REAL - TIME FORCE PROTECTION SIMULATION AND TRAINING SYSTEM USABILITY EVALUATION

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ABSTRACT

The Air Force Research Laboratory is conducting research and development of a computer-based simulation capability to support training in decision-making and team coordination for security forces ground operations. Simulation software supports the interaction (over a local area network) of trainees with each other and with computer-generated forces (CGF's) that simulate behavior and communications of enemy, neutral, and friendly troops and civilians. Radio functions allow multi-channel communication among instructors, trainees, and CGF's. Trainees can practice decision-making and team coordination in a number of scenarios with varying threat and environmental conditions. Current systems are too costly for training large numbers of security forces because they require an on-site technician to develop simulation exercises, control the exercise, serve as role players, task CGF's, and support after action reviews. Consequently, design and development of a simulation control interface that can be directly used by instructors and trainees is an important R&D objective. For the security forces simulation capability the goal is to design a control interface that instructors can learn to use in two hours and trainees can learn to use in thirty minutes. To achieve this goal, a Windows-based control interface (with a number of video game features) was adopted as the initial point of departure. Menu options were developed to correspond to the standard mission planning procedures used by security forces and drag-and-drop functions were developed to replace menu options to contribute to usability. We have conducted an evaluation of the initial user interface with school instructors and trainees. The paper describes the emerging control interface, the approach to and outcomes from a field evaluation of the interface to include actual times required for instructors and trainees to learn to use the system and instructors' acceptability evaluations. Lessons learned shed light on critical human-machine interface design issues for computer-based real-time training simulations.

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INTRODUCTION

United States Air Force security forces are responsible for military police services, installation security, airbase defense, military working dog functions, and combat arms training and maintenance. They have a central role in force protection. Whether security forces discover an improvised explosive device in a car or confront representatives of a non-governmental organization at an entry control point, such situations are reported to a command post whether it is called central security control, base defense operations center, or a law enforcement desk. Once situations are reported, quick and accurate decisions by security forces leaders and decision-makers are critical to handling the situation properly and fundamental to the protection of personnel and assets.

Command post exercises are periodically conducted to train personnel to respond to diverse situations. However, training decision-makers requires a large number of subordinate personnel to be deployed over a large area. Consequently, the command and control of security forces continues to be recognized as a high-emphasis training area (Weeks, Garza, Archuleta, and McDonald, 2001). As a result of established training needs and technology opportunities, the Air Force Research Laboratory is conducting research and development of an interactive simulation capability (Weeks and McDonald, 2002). Computer-driven, simulations are regarded as an affordable way to accelerate acquisition of expertise in leadership, decision-making, and team coordination; but, fielding such a capability depends on its usability and proven training effectiveness.

Guiding Principles

Since security forces are the second largest career field in the Air Force and there are limited funds for their training, affordability is a major design constraint. To meet these affordability goals, trainees and instructors should be able to operate the simulation without an on-site technician. Consequently, usability is a critical aspect of this development effort. After extensive interviews of security forces personnel, we have developed the following guiding principles for a computer based simulation for training Air Force Security Forces leaders and decision-makers:

- Learning how to use the simulation must require a negligible amount of time relative to the time spent training
- Simulation interfaces must be simple and intuitive
- Show trainees only what they would see in the field; no omniscient views of threat locations
- The user interface must simulate the primary tools used in the field, radio communications and a tactical map

Training Simulation

In order to understand the usability challenge, a description of the training simulation is presented below. An illustration of the training device is presented at Figure 1. It consists of standard personal computers connected by a local area network. Trainees are illustrated as a shift leader and subordinate flight leaders but could alternatively be a law enforcement desk sergeant and field officers, a flight leader and subordinate squad leaders, or a defense force commander, operations officer, and area supervisors. The capability is being developed as a multi-echelon, command and control, training device to support different training requirements.

The computer display simulates the tactical map used in the field. Trainees read an Operations Order and place overlay symbols on the map using the mouse and menu selections. Placing these symbols on the simulated map populates the virtual world with assets (e.g. riflemen, fighting positions, barriers, sensors, entry control points) in their areas of responsibility. They also use menu commands to initiate actions such as patrols and to set rules of engagement for the computer generated forces (CGF's) under their command. Once the trainees have completed their plans, the instructor initiates the exercise in which threat, friendly and neutral CGF's enter the facility.

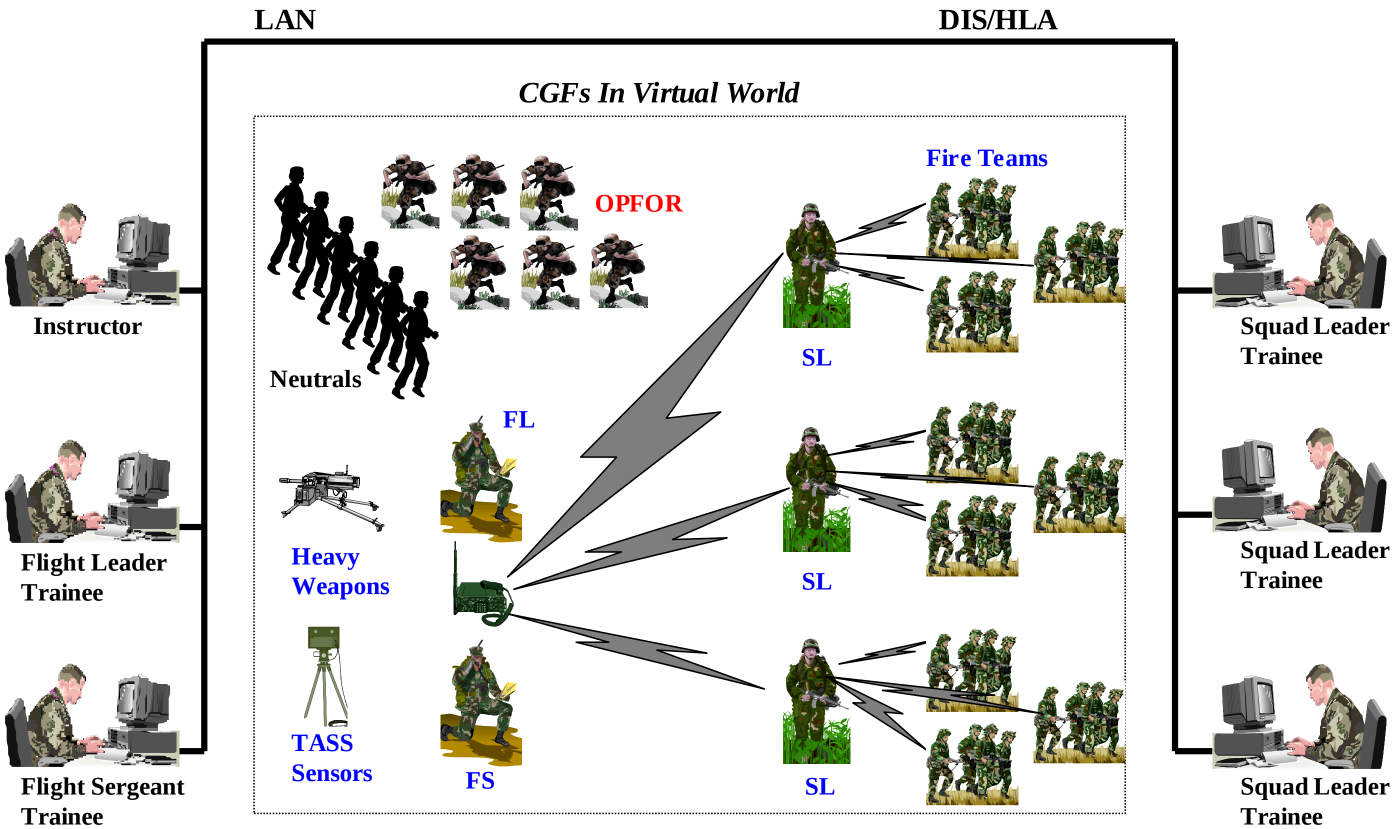


Figure 1. The Training Device

Friendly CGF's under the command of the trainees issue verbal situation reports (SITREPS) over their assigned radio channels. Trainees hear the SITREPS over their headsets, see sensor alarms and communicate with other trainees using the simulated radio channels. They then make decisions and issue orders to their CGF's via menu selections.

Subject matter experts indicated that one of the most difficult tasks for young leaders and decision-makers to learn is situational awareness (the ability to mentally picture the locations and movements of threats, neutrals and friendlies based on SITREPS and sensor alarms. During the planning phase, trainees place friendly icons on the simulated map just as they would an actual map.

When the exercise starts, these icons do not move when commanded to do so because annotations on a real tactical map do not move automatically. Trainees move the friendly icons based on mental dead-reckoning and location reports. Needless to say, the actual locations of threats and neutrals are not displayed on the simulated tactical map, because trainees would not learn situational awareness. As friendly CGF's issue SITREPS, trainees can place suspected location icons for threats and neutrals on the simulated map, just as they do in the real world. During the AAR, all verbal communications over simulated radio channels are played back in real time. In addition, the actual locations of threats, friendlies and neutrals are replayed in real time along with the suspected location icons. These comparisons are believed to promote the development of situational awareness skills.

The simulation has over 450 functions to be controlled by the trainees and instructor during the mission planning, mission execution and AAR. This is the reason usability has been given such a high priority in this development effort.

Usability Issues

Since there is no rigid sequence required for conducting mission planning, we chose to use a mixed initiative dialogue with direct manipulation of data. We chose menu selections as opposed to a user command language because of our desire to have trainees learn to use the simulation quickly (Smith &

Aucella, 1983; Ambardar, 1991) and begin training. We chose menu selections to control CGF's because English language dialogue is "unsuitable where an operator input must be interpreted with precision (because of ambiguity)" (Boff & Lincoln, 1988). Although speech understanding systems have come a long way in recent years, this technology is still an active research topic and not ready for use as a routine dialog tool in a command and control simulation. The menu hierarchy was designed to be wide and flat with a maximum of 10-15 options at each level per the DoD Technical Architecture Framework (1996).

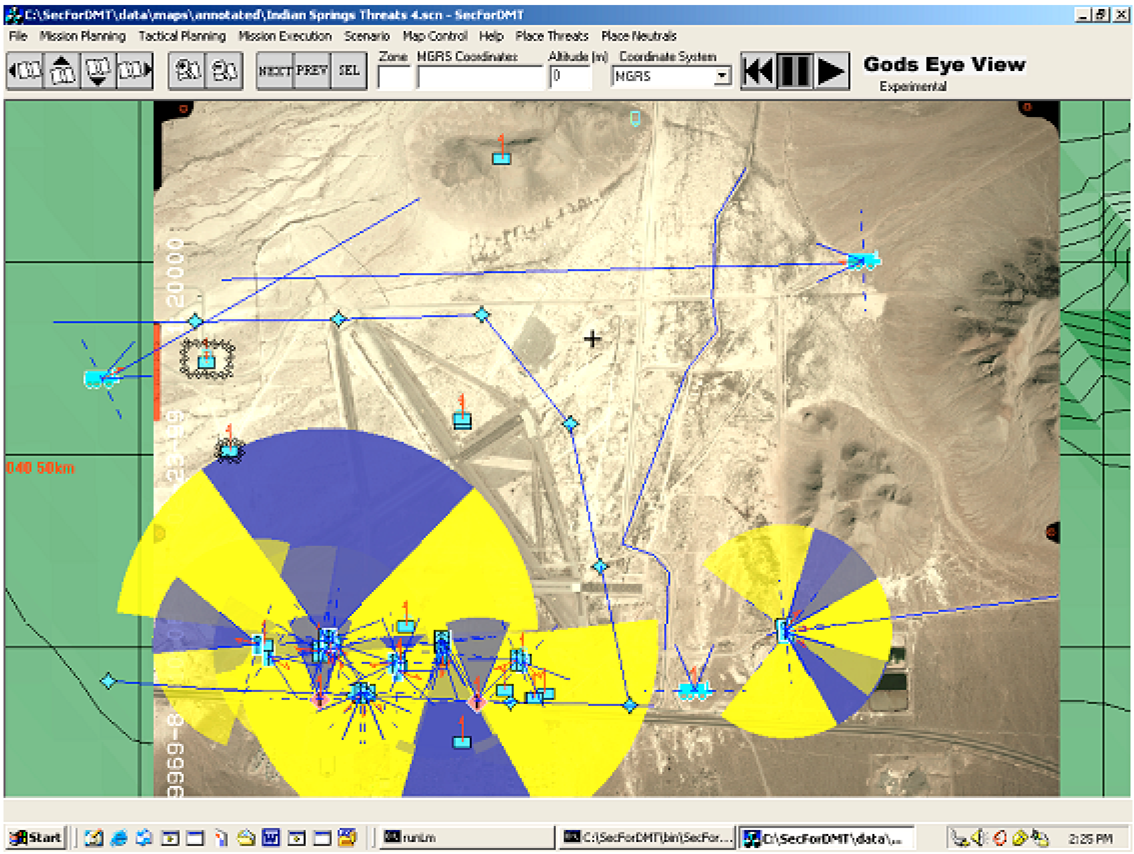


Figure 2. The Simulation Control Interface

RESEARCH OBJECTIVES

Research objectives include development of a usable control interface, realistic behaviors for CGF's, development of simulation exercises to support learning objectives, and evaluation of system usability, model validity, and training effectiveness. The research and development project includes multiple field evaluations with participation of end users. The development strategy is to collect evaluation feedback and apply it to refinement of the capability in an effort to accelerate transition to the field.

The initial evaluation (and the issue addressed in this paper) consists of assessments of the usability of the simulation control interface. Usability assessments include measures of training time for instructors and trainees and instructors' ratings of the usability of the control interface. The evaluation concludes with assessments of the overall value of the training device and draft training scenarios for mission planning and execution of the defense. The purpose of this paper is to describe outcomes obtained from initial field evaluations. Summary conclusions are expected to shed light on lessons learned and the promise of computer-based training simulations for the future.

USABILITY EVALUATION APPROACH

Brewer, Armstrong, and Steinberg (2002) state "usability testing … verifies that a system or product design meets our expectations for usefulness and satisfaction before we move into production (p 403)." They define usability as "the degree to which the design of a device or system may be used effectively and efficiently by a human (p 403)" and point out that

the important issue in arriving at a definition is how to measure usability so that measurements can be used to improve the design. Brewer, et al. (2002) outline three general approaches to usability evaluation including surveys (using self-report data collection methods), usability inspections (specialists scrutinize a design according to a systematic approach and judge its acceptability against certain criteria), and experimental tests (based on quantifying operator performance using controlled data collection techniques).

Usability inspection best describes the approach to the initial evaluation. The specialists were instructors assigned to different security forces training squadrons. They were first trained to use the simulation control interface; then, they evaluated the interface on critical criteria, identified problems, and recommended improvements. These specialists were not experts in software or human factors engineering, but they did represent a final authority for usability, the end user.

Trainees are also end users of the simulation capability. They will be expected to control the simulation interface and based on resource availability create computer models for sensors, obstacles, weapons, CGF's, and communications. Trainees participated in the initial evaluation by providing baseline training times for simulation control tasks representative of those they would perform during a simulation exercise.

The complete training system consists of several computers linked by a local area network. However, for initial field evaluations only one laptop computer was used. The strategy is to modify the control interface on the basis of change recommendations before taking the complete training system to the field for the final evaluation.

To describe the usability inspection approach, Brewer, et al (2002) present an example of a computer interface. It is a single dialogue box. The usability issue is whether to position control buttons on the bottom left or bottom right of the dialogue box. Compared to the dialogue box described by Brewer, et al (2002), the interface evaluated here is immense. It consists of over 450 different controls including menus, tools, dialogue boxes, intermediated control windows, and simulation window symbols. One recommended approach to usability testing is based on presenting a control interface to end users, not informing them how to use it, observing if they can deduce how to use it, and requesting feedback concerning improvements (Andre, personal communication, 2003). Although this would be a useful approach for the interface described by Brewer, et al. (2002), it was not used here. In addition to the great number of interface controls, most participants in the field evaluation had no experience with simulation capabilities like the one evaluated. For them it was a novel experience; so it was impractical to adopt a discovery learning approach. To minimize the duration of the evaluation period while obtaining meaningful input, it was necessary to familiarize participants with the interface in advance.

The simulation control interface used for the preliminary evaluation was delivered with Version 2.0 of the simulation software and is presented at Figure 2. It consisted of a simulation window in which a digital map is presented; a menu bar consisting of menus, menu options, and menu option labels; a tool bar consisting of tool bar buttons and information windows; a pop-up menu presented in the simulation window and accessed through a right mouse click, a mouse, and a standard computer keyboard. The radio microphone and headset and simulation logger were not included in the preliminary evaluation. These interface devices will be tested during evaluation of the complete training system.

One of the greatest obstacles to incorporating such simulations into formal training is the support costs. For training simulation systems currently available, on-site technicians are required to design and develop simulation exercises in support of learning objectives and must be present during the instructional event to control the exercise, serve as role players, task CGF's, and provide simulation replays to support after-action reviews. Costs of support requirements are a barrier to fielding simulation technology for formal training; hence, design and development of a simulation control interface that can be directly used by instructors and trainees is an important research and development objective. At the beginning of the project, a usability standard was established and defined as the time required to learn to use the device. The expectation is the shorter the training time; the greater the usability. The intent is to compare the usability standard with observed and maximum training times as a guide for system modifications. Training time standards are that instructors will be able to be trained to use the device in 2 hours and students will be trained in 30 minutes. Evaluation of training time was one of the objectives of the initial evaluation.

To begin the evaluation, each participant was presented a briefing describing the complete training system and the training concept. After the briefing, they were asked to read and sign a disclosure and consent form and to complete a background questionnaire to obtain

information about their time in service, training, and experience with computers. The evaluation was conducted one participant at a time. This approach minimized adverse impact on day-to-day activities of the training group that could have occurred if several participants were tasked to support the evaluation in mass. Each participant was trained to use the control interface illustrated in Figure 2 and their training time was recorded. It was explained to each participant that they were not being evaluated; rather their training time was being recorded to derive an estimate of training time for evaluating the device. Threshold training time was defined as the maximum time that could be allocated for a user to be trained to use the device. After training on all tasks, instructors were asked to estimate maximum training time for instructors and for students.

The simulation control interface included over 450 control options. We define control options as the total number of menu items, radio buttons and fill-in-the-blank dialogue boxes. The largest number of items on a menu was ten and the deepest nesting of a menu was four levels. Rather than attempting to train participants on all control options, samples of tasks were selected to represent those likely to be performed during a simulation exercise. Task selection involved a trade-off between practicality and an evaluation of all control options. A balance was sought between what participants might regard as an intolerably long evaluation period and evaluation of all control options. Tasks for both instructors and trainees consist of three categories representing control of the simulation window, placing resources, and tasking CGF's. Trainee tasks are a subset of instructor tasks and exclude tasks only instructors would perform like creating threat and neutral CGF's. Instructor and trainee tasks are non-random samples from the population of tasks. Rather than randomly sampling and presenting tasks, they were carefully selected and sequenced for meaningfulness. Although the main purpose was to evaluate the training device, the field evaluation was the first opportunity for instructors to observe the capability; so a secondary goal was to make the experience meaningful. However, the experience was time limited. If more tasks had been selected for the evaluation, total observed training time would have been greater. However, the more tasks selected; the greater the length of the evaluation period, and the less likely it would be to obtain participants' willing cooperation and meaningful input.

Measures of training time were obtained separately for each participant. The participant was told how to perform each task, she or he was shown how to do it, and asked to independently perform the task with assistance. They were asked to indicate when they had learned to use interface controls for the task. When the participant stated she or he had learned to perform the task, training time was declared complete. Immediately after training for each task, the participant was asked to perform the task independently. It was noted whether it was performed with our without assistance. It was assumed that if the participant performed the task without assistance, they had learned to use simulation interface controls. If the participant asked for assistance, recorded training time for that task for that participant was doubled. Task training time was cumulated over all tasks to obtain an estimate of training time for a single participant. Training time was averaged over trainees and instructors separately to estimate total training time for each group.

Trainee participation was limited to learning how to perform each task. Trainees did not provide evaluations of the training device. Evaluations were conducted only by instructors. After training for each task, the instructor rated the controls used to perform the task on clarity, effectiveness, efficiency, and simplicity; always in that order. Clarity was defined as the degree to which interface controls were clear and understandable. Effectiveness was defined as the degree to which interface controls allowed the task to be performed. This criterion factor provided an opportunity for instructors to recommend additional functionality to improve the effectiveness of controls. Efficiency was defined as the degree to which the controls used in performing the task allowed quick performance. Simplicity was defined as the degree to which the logic of using the controls was complex or easy to understand. Extremes of the rating scale for simplicity were anchored with verbal anchors, "Extremely High Simplicity" and "Extremely High Complexity". Rating scales for clarity, effectiveness, and efficiency used similar scales. The process of obtaining ratings guided the instructor to think about specific criteria for usability and provided indicators of order relationships among tasks for each criterion. After rating the control interface for a task on one of the criteria, instructors were asked to identify problems and recommend improvements.

At the conclusion of the evaluation period, instructors were asked if they agreed that observed simulation scenarios would support learning objectives for mission planning and execution of the defense and whether or not they believed the simulation capability would add value to training.

RESULTS

A total of 20 instructors participated in the evaluation (10 instructors from the 96th Security Forces Ground Combat Training Squadron located at Eglin AFB, FL and 10 instructors from the 37th Training Group located at Lackland AFB, TX). The first evaluation was conducted at the 96th Ground Combat Training Squadron where the original task list consisted of 24 tasks. Each of the first 7 instructors dedicated 6 hours to the evaluation including lunch and breaks. After instructor 7, the task list was reduced to 18 tasks to minimize the burden on participants. The 18 task list required approximately 4 hours for each instructor. The 18 task list was used for all instructors from the 37th Training Group. The results reported in this paper are for the 17 tasks common to the first and second task list. Participants also included 10 trainees from the 343 Training Squadron who had recently graduated from security forces initial-skills training and were awaiting assignments.

On average, the instructors were 29.35 years of age. There were 3 captains, 1 senior master sergeant, 1 master sergeant, 4 technical sergeants, 9 staff sergeants, and 2 senior airmen. All enlisted personnel serving as instructors were at the journeyman skill level or higher within the security forces career field. They had an average of 9.4 years of service and 1.7 years in their current position. They indicated they spend an average of 38.6 hours per week using computers and in the preceding year played computer games an average of 5.65 times. Trainees participated in learning how to perform 13 tasks.

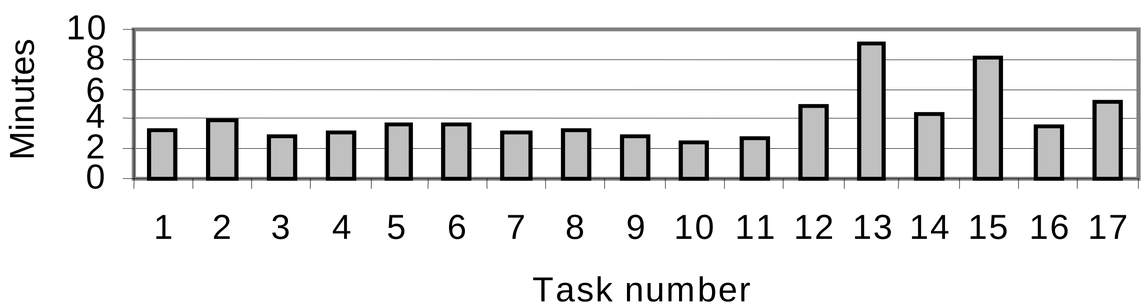
- Pan, zoom in/out on map
- Use range and bearing tool to determine distance on map
- Determine height using contour lines and display
- Place CGF in fighting position, set fields of fire
- Determine dead space using intervisibility tool
- Assign field phones to fighting positions
- Create, place, move, orient, delete
    - Obstacle
    - Sensor
    - CGF
    - Primary Fighting Position
- Assign radios and call signs to CGF's and generate location reports
- Task vehicle to conduct patrol along assigned route
- Retask CGF to go to map location

Instructors were tested on four additional tasks.

- Create, place, move, orient, delete
    - Threat CGF's
    - Neutral CGF's
    - Facilities and Aircraft
- Create instructor-generated SITREP

On average, trainees were 19 years of age. Five of the trainees possessed the rank of airman first class and 5 possessed the rank of airman basic. All trainees had acquired the apprentice skill level. They had an average of 6 months of service. They indicated they spend an average of 4 hours per week using the computer and in the preceding year played computer games an average of 3 times.

Figure 3. Average task training time for 20 instructors (Summation over 17 tasks = 1 hr 16

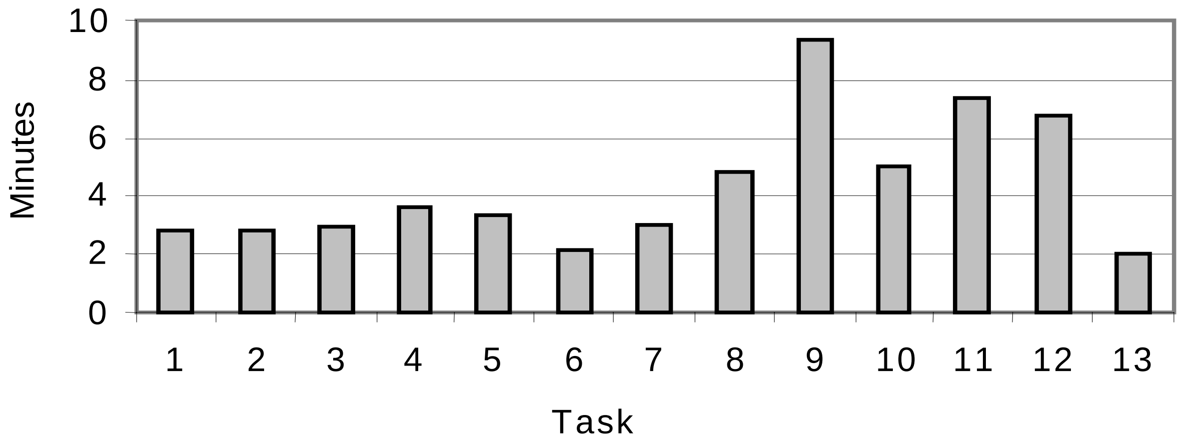


Maximum allowable instructor training time = 4 hr 39

Figure 3 presents the observed task training time for 17 tasks averaged over instructors. Most tasks required 5 minutes or less training time. The instructor training time usability standard was 2 hours. Figure 4 indicates that the observed, average training time for instructors summed over the 17 task sample is 1 hour and 16 minutes. Observed training time for the 17 task sample fell below the pre-established two-hour standard.. After task training, each instructor was asked to estimate the maximum amount of time that could be allocated for instructors to be trained to use the device. Maximum instructor training time was estimated to be 4 hours and 39 minutes, on average.

Figure 4 presents the observed training time for 13 tasks averaged over trainees. Most of the tasks required 5 minutes or less training time. For trainees, the training time usability standard is 30 minutes. Figure 4 indicates that the observed, average training time for students summed over the 13 task sample is 56 minutes. Observed training time for the 13 task sample exceeded the pre-established 30 minute standard for student training time. Each instructor was asked to estimate the maximum amount of time that could be allocated for students to learn to use the device. Instructors estimated the maximum student training time at 4 hours and 9 minutes, on average. For instructors, the procedure was to learn to use interface controls then rate the control interface on clarity, effectiveness, efficiency, and simplicity; always in this order. Figure 5 presents average interface usability ratings for each criterion factor. Even though data collection was arranged on a task-by-task basis, instructors were told that the collection of interface controls used to perform the task were the target for each rating. For each usability factor, a rating value of 5 represents an “Average” rating, while 7 and 8 represent “High” and “Very High”. Aggregate ratings for all tasks and criterion factors were above average. These results indicate instructors believed the control interface was easy to understand, it was effective, it allowed them to accomplish tasks quickly, and the logic of operations required for using the controls was easy to understand.

Figure 4. Average task training time for 10 trainees (Summation over 13 tasks = 56 min 2



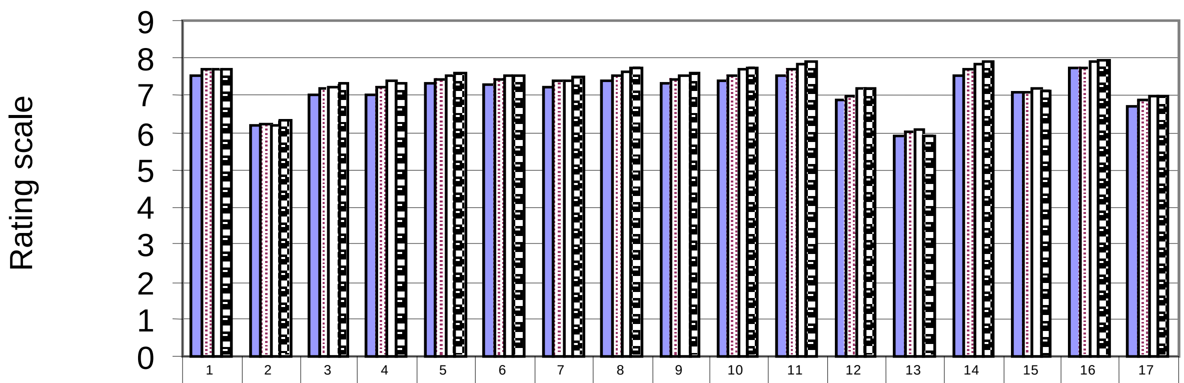
Maximum allowable student training time = 4 hr 9

Although the instructors were enthusiastic about the ease of use and training potential of the system, everyone always has recommendations for improvements. The 20 instructors provided a total of 310 change recommendations. These change recommendations consisted of suggestions to improve deficiencies in usability and suggestions to add functionality. The most frequently recommended changes are listed below:

- Migrate as many options as possible from the top of display menu to the right click menu.
- Make map panning and zooming functions more efficient

- Fix grid lines at 1 Km instead of making them dependent on zoom level
- Simplify turning contour lines on and off
- Show max range of weapons in addition to max effective range currently shown
- Include display of LOGDET assets used
- Implement copy/paste option for placing assets
- Allow instructor to cause communications failures
- Simplify tool for generating friendly SITREPS
- Modify colors of asset icons

Figure 5. Average interface usability



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Clarity	7.5	6.2	7.0	7.0	7.4	7.3	7.3	7.4	7.3	7.4	7.5	6.9	6.0	7.6	7.1	7.8	6.7
Effectiveness	7.7	6.2	7.2	7.2	7.4	7.4	7.4	7.6	7.5	7.6	7.7	7.0	6.0	7.7	7.1	7.7	6.9
Efficiency	7.7	6.2	7.3	7.4	7.5	7.5	7.4	7.7	7.6	7.7	7.8	7.2	6.1	7.8	7.2	7.9	7.0
Simplicity	7.7	6.3	7.3	7.3	7.6	7.6	7.5	7.8	7.6	7.8	7.9	7.2	5.9	7.9	7.1	8.0	7.0

Finegold, L.S., Withman, R.L., & Kuperman, G.G. (2001) found similar results concerning map zooming and panning. They recommended that users be able to zoom directly to the desired magnification level and map center without going through intermediate zoom values and pans. These changes along with the great majority of other changes have been implemented in the next spiral development, but instructor evaluation will occur after the due date of this publication.

After task training and the process of providing usability ratings, each instructor was asked to provide summary evaluations. All 20 instructors except one agreed the device would add value to training. All agreed the draft training scenarios they observed would support learning objectives for security planning; and all but one instructor agreed the capability would support learning objectives for execution of the defense.

DISCUSSION

Although observed training times provide useful baseline estimates of usability, they have limitations. The initial evaluation did not include the simulation logger or the radio microphone or headset. If tasks for these devices had been included, training time would have been greater. Training time for these devices will be estimated when the complete training system is evaluated.

Because it was necessary for reasons of practicality to limit the number of tasks evaluated, training times are underestimates. Only a representative subset of tasks were used for instructors and trainees. Observed training time underestimates total training time for all 450 interface control options.

For instructors, total observed training time is an overestimate. During the training period for each task, instructors often discussed problems and recommended needed capabilities. The result was that total observed training time includes time required for training and time for non-training interactions.

Better estimates of observed training time are needed. It would be desirable to obtain a more accurate estimate of observed training time that excludes time for non-training interactions, includes tasks for use of the radio headset, and simulation logger, and a greater

number of representative tasks while maintaining a reasonable time for the evaluation period. Multiple evaluation periods may be necessary if acceptable to participants.

Even though there are limitations in observed training time, it is important to understand the alternatives. If observed training time for instructors were doubled, it would still be less than the allowable training time specified by the instructors and substantially less time than required for other training simulation capabilities available today. For example, consider a joint tactical simulation currently in use. On a separate occasion, the co-author observed security forces personnel being trained on this system to support installation security evaluations. Observation of "user training" for the system indicated 7 security forces personnel varying in rank from staff sergeant to master sergeant satisfactorily learned to task CGF's to move, dismounted and mounted, and shoot, direct and indirect-fire weapons, in 1 and ½ eight-hour, training days. Experts indicated they had learned to operate the system over a period of months. If the training time for the system is the comparison point, SecForDMT offers a significant advantage by avoiding lengthy training times for end users. This reduced training time can be attributed primarily to its greater usability.

LESSONS LEARNED

Even for a simulation with 450 functions the use of established usability techniques can make the system usable by novices in a very short time. The use of a mixed initiative dialogue with direct manipulation of data has been shown to be an effective means of allowing novices to operate a war game simulation quickly. Control of CGF's and other assets via right-click menu selections was intuitive and easy for novices to master. Since panning and zooming a display can consume significant time, providing trainees with tools to pan and zoom and center a display in one step without going through intermediate zooms is critical. To take advantage of population stereotypes, design the interface similar to Windows and video game user interfaces. Although students' observed training time of 56 minutes exceeded the self-imposed 30-minute standard, the maximum training time available for training students (4 hours) suggests that the capability may still be useful for training. Due to the emphasis on usability in the design of SecForDMT, instructors rated control interface usability high and very high for almost all tasks. Most importantly, our research indicates that simulation interfaces can be designed for control by trainees and instructors without an intermediate controller.

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